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#6 Simple Tensile Testing of Polymeric Films and Sheeting

Submitted by: Melanie Stewart,
Stow-Munroe Falls High School, Stow, OH 44224

I. INTRODUCTION

Description

These activities investigate the tensile strength and percent elongation of various polymer films or sheeting. Student will pull tensile bars applying stress and feeling the differing strain produced. They will also calculate percent elongation of different materials comparing the differences between plastics and elastomers. These are modifications of ASTM D-638 which is the industrial standard for tensile testing.

Student Audience

These activities can be used in basic science classes through university chemistry and physics classes.

Goals for the Experiment

The student will:

- compare and contrast tensile strengths of various film samples to commercial uses,
- compare tensile strength of materials along and perpendicular to machine direction,
- calculate the percent elongation of various polymeric materials,
- use results to describe the differences between elastomers and plastics, and
- apply tensile and elongation results to service use and applications.

Recommended Placement in the Curriculum

This experiment is recommended for use in the discussion of any of the following topics:

- molecular orientation,
- polymers,
- stress and strain, and
- physical testing.

II. STUDENT HANDOUT

Simple Tensile Testing of Polymeric Films and Sheeting

Scenario

In the past, the grocery chain Old Fashioned Foods has provided only paper grocery sacks. O.F.F. is now planning to offer its customers the option of having their groceries packed in plastic bags. You have been hired as an outside consultant to test polymer films from samples provided by bag manufacturers. The first test is to determine tensile strength, the pulling stress required to break a sample. This will measure the relative ability of the bags of different materials to hold heavy groceries without breaking.

Background

Tensile testing is the measurement of the ability of a material to withstand forces pulling the sample apart and the extent it stretches before breaking. When a tensile sample is pulled, one end of the sample is clamped and stationary while the other is pulled at a constant velocity until the sample breaks. By definition, stress is an applied force or system of forces that tends to strain or deform a body. It is also the internal resistance of a body to such an applied force. You will feel the stress when pulling on the samples in these activities. Strain is the change in length per unit of original length which is caused by the pulling. Figure 1 below shows a typical curve that results from a tensile test.

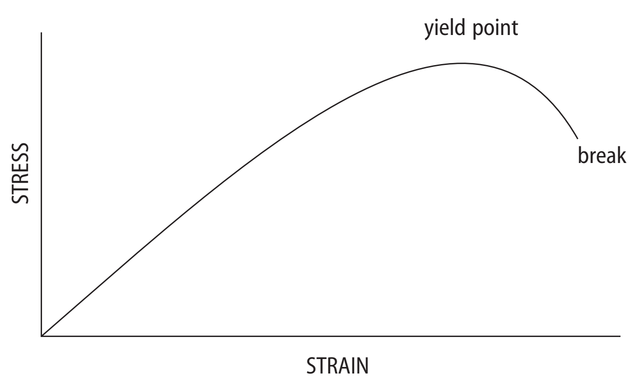

Figure 1: Typical tensile test curve

The yield point shown on the graph is the point at which permanent deformation of a stressed specimen begins to take place. It is also the first point at which the strain increases at a higher rate than the stress increases.

Tensile testing is generally done on samples shaped like "dogbones." The size of the sample is relatively unimportant but the shape is critical. Nearly all of the deformation will occur in the narrow center (the gage) of the sample and is thus unaffected by the method by which the sample is attached to the testing mechanism. Accurate and repeatable data depends on the uniform distribution of the load throughout the gage section and thus it is important that the gage be dimensionally uniform.

Tensile strength is the most often specified property of plastic materials used to indicate the inherent strength of the material. Tensile strength is dependent on the molecular structure and the orientation of the polymers within a particular sample, as well as any fillers or reinforcements that may be compounded into the polymer. Anisotropic materials, those for which the molecular orientation or the orientation of fibrous reinforcements is unidirectional will vary in tensile strength depending on whether the measurement is in the machine direction (MD) or in the transverse direction (TD). Materials that are biaxially oriented will show greater tensile strength and those which have random molecular chain orientation will show lower tensile strengths.

Tensile strength and elongation are affected by the velocity at which the sample is pulled. When samples are pulled slowly, the molecular orientation has opportunity to readjust with greater percent elongation. Samples pulled rapidly will fracture with lower percent elongation of the sample. Elongation and the resulting permanent deformation also differ between elastomers and plastics. Both materials stretch but elastomers will return to their original length with little permanent deformation whereas plastics will be permanently deformed.

The activities will investigate differences in tensile strength based on velocity, molecular orientation, and material type. Elongation testing will be used to investigate the differences between elastomers and plastic.

Safety, Handling, and Disposal

While procedures in these investigations are not duly hazardous, proper laboratory safety precautions are absolutely necessary.

- When testing elastomers for elongation, be careful not to release the material, snapping your hand or hitting another student.

Materials

Sample Preparation

- plastic film samples
- tensile bar template
- permanent marking pen
- scissors
- stapler
- latex materials

Investigation #1

- tensile bars prepared in Sample Preparation

Investigation #2

- tensile bars prepared in Sample Preparation
- ring stand and ring
- 2 pieces 25-cm heavy string or cord
- 2 plastic 2-liter bottles

- plastic tub or bucket to catch water
- one of the following
  - plastic funnel and metric volume measuring container
  - buret

Investigation #3

- plastic film and latex strips prepared in Sample Preparation
- permanent marking pen
- meter stick

Sample Preparation

Investigations #1 & 2

1. Determine the grain of the plastic film by holding it to the light. The grain is often visible as striations, streaks, or lines in the film in the direction the polymer was extruded. This reflects the machine direction of the sample. The plastic film was most likely made by the polymer being melted, extruded through a die, and blown into a large bubble and then collapsed and taken up on a spool. The film may be anisotropic; that is, it may have different properties parallel and perpendicular to the grain.
2. Fold the film so multiple tensile bars can be cut with the grain. Position the tensile bar template (Figure 2, page 9) with the grain and trace with the permanent marker. (Or, for Investigation #1 only, make simpler but not authentic 3 inch by 5 inch rectangles in place of the tensile bar. An index card can be used as a template.) Staple around the edges to keep the layers in position while they are being cut out.
3. Carefully cut out the tensile bars as smoothly as possible. Remove the staples carefully, trying not to tear the film.
4. Repeat as needed until you have enough tensile bars for the investigations you will perform:

- Investigation #1: 2 of each sample for each group member
- Investigation #2: 3 of each sample
  Extra tensile bars can be made in advance or on an as needed basis.

5. Repeat the sample preparation steps but this time prepare samples cut against (perpendicular to) the anisotropic nature of the film.
6. Repeat Steps 1–5 with additional types of film as indicated by your instructor. You may be testing different thicknesses of a single polymer film and/or the same thickness of different polymer films.

Investigation #3

1. Cut the plastic and elastomer samples into strips 2–2.5 cm wide and 20 cm or longer both parallel and perpendicular to the grain. Cut at least 6 strips of each material and direction being tested. Note that for some elastomer samples you may only be able to prepare strips in the machine direction.

Procedure

Investigation #1

Plastic film is used for a variety of food packaging applications such as in deli, meat, and produce departments to wrap merchandise. Other film is sold to wrap food at home. Inherent strength is needed to seal and protect food while sufficient stretch is necessary to make a tight seal and an appealing surface. Film is also made into bags for carrying groceries, merchandise, or trash. Generally, the bags are made such that the anisotropy is along the length of the bag to provide the greatest strength in that direction. That is, when the chains are oriented along the length of the bag, the strength comes from the covalent bonds in the polymer rather than from intermolecular attractions. The following activity will provide an opportunity to test for the inherent strength and the stretchability of the films tested. After determining the service needs of the film, you will relate the tensile results to the film's application.

1. Hold the ends of one tensile bar that is cut so the length of the sample is parallel with the grain. Gently and evenly pull the sample. Note the strain that develops as the material is pulled.
2. Repeat with a sample cut perpendicular to the grain of the material, pulling at the same rate.
   a. Compare and describe the difference in strain between the two samples. (If no difference is evident or if necking, a phenomena where the loaded tensile specimen begins to elongate rapidly because of a local area of thinning-down, repeat Steps 1 and 2 while pulling at a faster rate.)
3. Repeat Steps 1 and 2 pulling the samples very slowly.
   a. Compare and describe the difference in strain between the two samples (parallel and perpendicular to anisotropy) and between the two sets (slow pull vs. very slow pull).
   b. Compare your results in terms of inherent strength and the application of the sample tested.
4. Repeat the experiment with other types of film material or gather information from other groups (as indicated by your instructor) and compare service needs with tensile results.

Investigation #2

The following is a more quantitative version of Investigation #1.

1. Tie one end of the string to the 2-liter bottle. Screw the ring onto the ring stand.
2. Begin with a tensile bar cut perpendicular to the grain of the film. Tie one end of the tensile bar to the ring on the ring stand. Tie the other end to the string tied to the 2-liter bottle. Do not stretch the film. If the film is stretched during this process, start over with a new piece of film.
3. Adjust the position of the ring stand such that the bottle hangs freely. If there is any doubt that the ring stand is stable, hold it in place while performing the procedure. Do not hold the bottle up. Position the bucket or tub under the bottle.

4. Using a funnel and a metric volume measuring container (or a buret), slowly add water to the bottle. Keep track of how much water is added and record the total volume added when the film breaks.
5. Repeat Steps 2-4 with two more of the tensile bars of the same material also cut perpendicular to the grain of the film. Calculate the average volume of water needed to break the film and the mass of that water using a density of 1.0 g/mL.
6. Repeat Steps 2-5 using tensile bars of the same material but cut parallel to the direction of the grain. The material will probably be stronger in this direction so a second 2-liter bottle may need to be added and (partially) filled with water before the film breaks. If so, tie the second bottle to the first bottle.
7. Repeat Steps 2-6 with a different type of film as instructed by your teacher or gather information from other groups to compare with yours.
8. Answer the following questions:

a. What are some potential sources of error in this investigation? Explain.
b. Describe the broken sample pieces (including location of breaks, sample deformation characteristics, etc.) What conclusion might be drawn from each of these observations?

Investigation #3

This investigation will use tensile and elongation testing to differentiate between various polymers including plastics and elastomers.

1. Using a permanent marker, mark the samples 5 cm from one end across the width of the sample. From this marking, measure 10.0 cm and mark the sample across the width of the sample. The area between the marks is the elongation test area. Mark all test samples.

2. Tape a meter stick or a metric tape measure to the lab table top. Place the first test sample so that one of the marked lines is lined up with the zero point of the measuring device. Use the heel of your hand to hold it in place such that the heel of your hand and the marking are in line with the zero point.

3. Measure the distance to the second line to 0.1 cm and record it as the initial length.

4. Holding the sample just beyond the second line, slowly stretch the as far as possible without it breaking. Record the final length between the marked lines. Allow the sample to relax slowly without completely releasing it. **Be careful not to release the stretched elastomer, snapping your hand or another student.**

5. Describe the stretched sample.
6. Calculate the percent elongation as a percentage of the initial length.
7. Repeat for a total of 3 of the same samples and calculate the average percent elongation.
8. Repeat Steps 2-7 for each of the samples (parallel and perpendicular to the grain) of each material and record in a data chart.

9. Complete the following based on your data from all the investigations:

    a. Compare and contrast the elongation results of plastics and elastomers.

    b. What would happen to your percent elongation results if you increased the pulling speed on the test samples?

    c. How do results of percent elongation testing effect service use of the materials tested?

Questions

1. What happens to the polymer chains when the sample is stretched?
2. Describe what processing parameters in blowing film affect the ratio of tensile strength in the machine direction (MD) and in the transverse direction (TD).
3. What structural differences account for the differences in behavior between plastic films and elastomers?
4. How does density or crystallinity and polymer type (LDPE, LLDPE, HDPE) affect tensile strength and elongation?

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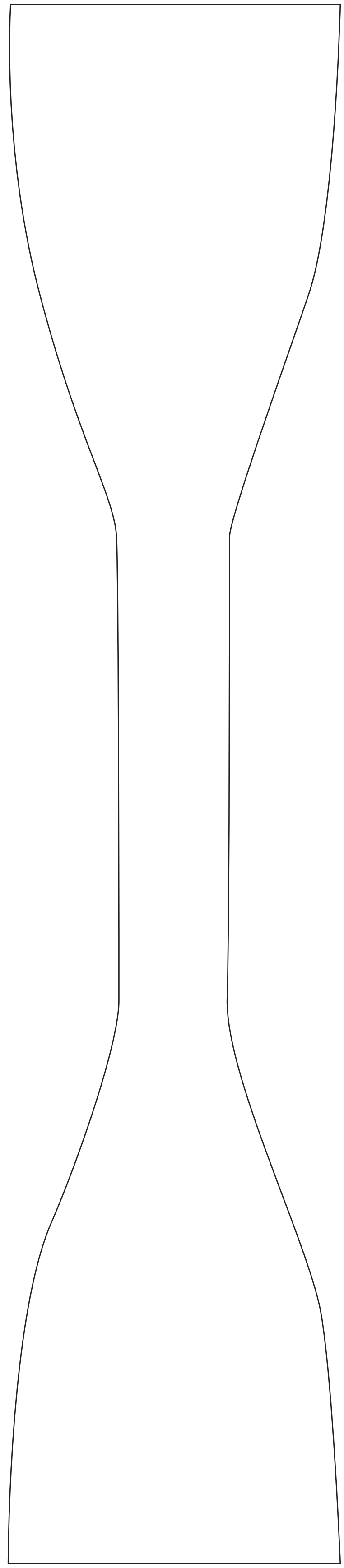
Figure 2: Tensile Bar Template



III. INSTRUCTOR'S NOTES

Simple Tensile Testing of Polymeric Films and Sheeting

Purpose

These activities replicate industrial tests common in the polymer industry. Students will compare films and/or sheeting based on qualitative tensile and quantitative elongation results to applications and uses. Comparisons will also be made of the tensile and elongation results with and perpendicular to the machine direction of the film or sheet material. Students will also investigate basic differences in elastomers and plastics.

Time Required

Each investigation of a single material can be completed in an hour or less. Completion of all three investigations using multiple materials will lengthen the time needed accordingly.

Suggested Group Size

These activities can be done with any size group in a laboratory setting or a classroom. Groups of three or four student with sharing of information between groups is recommended.

Materials

<u>Sample Preparation</u>

Per group

- plastic film samples (trash bags, grocery bags, insulation, sheeting, etc. Provide different thicknesses of a single polymer film and/or the same thickness of different polymer films.)
- tensile bar template (A sample template is provided for use as is or enlarged onto legal size paper.)
- permanent marking pen
- scissors
- stapler
- latex materials (rubber bands, gloves, tourniquet straps, etc.)

<u>Investigation #1</u>

Per group

- tensile bars prepared in Sample Preparation

<u>Investigation #2</u>

Per group

- tensile bars prepared in Sample Preparation
- ring stand and ring
- 2 pieces 25-cm heavy string or cord
- 2 plastic 2-liter bottles
- plastic tub or bucket to catch water
- plastic funnel
- metric volume measuring device (100-mL graduated cylinder, 200-mL beaker, or metric measuring cup)

Investigation #3

Per group

- plastic film and latex strips prepared in Sample Preparation
- permanent marking pen
- meter stick

Safety, Handling, and Disposal

While procedures in these investigations are not duly hazardous, proper laboratory safety precautions are absolutely necessary.

- When testing elastomers for elongation, students should be careful not to release the material, snapping their hand or hitting another student.

Points to Cover in Pre-Lab

- Discuss tensile testing and its use industrially. This discussion can include a visit to the engineering department at the university, a local industrial visit, or a guest speaker from a local company to discuss their use of tensile and percent elongation data. Seeing an actual tensometer will help students envision their task.
- Remind students about safety when testing and stretching elastomers to prevent horseplay and avoid injury.
- Discuss the film extrusion and blowing process: The melted polymer is forced through a round metal slit, shaping it into a thin tube. The top of the tube is pulled together, sealing the tube, and then air is forced into the resulting bubble. The air is pressurized so that the bubble expands faster than the polymer flows into the die. This causes the bubble to stretch in the machine direction. In some cases, the bubble is also allowed to stretch in the direction perpendicular to the machine direction; that is, in the transverse direction (increasing its diameter). The latter case produces a biaxially oriented film. In either case, the bubble is gradually cooled and collapsed into a flat, two-layer sheet.
- Review anisotropy (having different physical properties when measured along different axes or directions) and the molecular orientation in polymers and elastomers. Using a fish net to mimic stretching elastomers is a good visual demonstration. Net can be purchased in sporting goods section of a discount store or netting used to wrap baskets at Easter can be purchased very inexpensively but usually only seasonally. The net mesh represents linear polymer chains that have been cross-linked. Slowly stretching then relaxing the net will demonstrate the elasticity without permanent deformation for students.
- Discuss how molecular weight influences properties. Generally increased average molecular weight results in increased toughness (impact strength), higher tensile strength at break, lower elongation, and better resistance to environmental stress cracking.
- For some students, you may wish to provide the equation for the %-elongation used in Investigation #3.

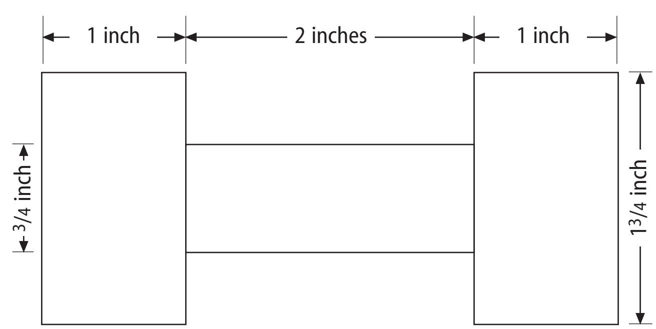
$$\frac{\text{final length} - \text{initial length}}{\text{initial length}} \times 100 = \text{\% elongation}$$

Procedural Tips and Suggestions

- The grain of the plastic film is not always easy to see. Provide samples where the grain is readily visible.
- If there is a weak point in a sample (such as a small tear in the side), it will break fairly quickly giving low values for tensile strength or elongation. Be sure that students are aware of this possibility. If their replicate samples show considerable variation, they should repeat the test with additional samples. For more experienced students you may wish to increase the number of repetitions from 3 to 5 or more and have them calculate standard and percent deviations and run t-tests on samples which appear to deviate significantly from the averages.

For Investigations #1 & 2:

- In pigmented film you should see small specks of pigment and streaks of color. These will help determine direction of extrusion. For these first tests do not use multi-layer film which is usually one color on one side and a different color on the other side.
- A large trash bag will make enough tensile bars in both directions for 3-4 students. Samples are easier cut when the trash bag is not unfolded from its packaged state and when very sharp scissors are used.
- An excellent comparison is between low density polyethylene and high density polyethylene bags for Activity #1. Because the LDPE is a more branched polymer it will elongate and stretch further then the HDPE which is more linear. The HDPE, stretched with the grain, will produce more strain than LDPE. When tested against the grain, LDPE will neck (narrow down and elongate) more while the HDPE will likely break very quickly with little strain. These results can then be compared to various types of trash bags, prices, utility, etc. Samples of LDPE (recycle code #4) and HDPE (recycle code #2) grocery bags are readily available at stores. Grocery store managers will often donate large numbers of bags to help educational programs.
- A smaller “dogbone” shape can be used in place of the template provided.



For Investigation #3:

- The width of the elastomer will dictate the width of the corresponding plastic sample. For better results all materials should have approximately the same thickness. Latex gloves can be used with heavy trash bags, latex sheeting from tourniquet strips or rubber bands can be compared to plastic sheeting sold in hardware and discount stores for tarps. The plastic film is sold in thicknesses from 2–6 mil (1/1000 of an inch), therefore a good match can be made.

Sample Results

The tensile strength of the films will vary with the type of material and with the direction of stretch. The films will have greater tensile strength in the machine direction (as shown by more water being added to the 2-liter bottle before the film breaks) than in the transverse direction. The polymer strands are aligned in this direction and tearing the film requires the breaking of bonds within the polymer strands. In the transverse direction, the polymer strands are held together only by relatively weak intermolecular attractions which require much less energy to overcome.

In sample tests, the garbage bags were the strongest, ziptop bags next strongest, and plastic wrap the weakest. This is what might be expected considering the needs of the products.

Students can expect results ranging from 2 to 200% or more elongation depending on the material. All plastics will show permanent deformation approximately equal to their elongation whereas the permanent deformation of elastomers will be small relative to their elongation.

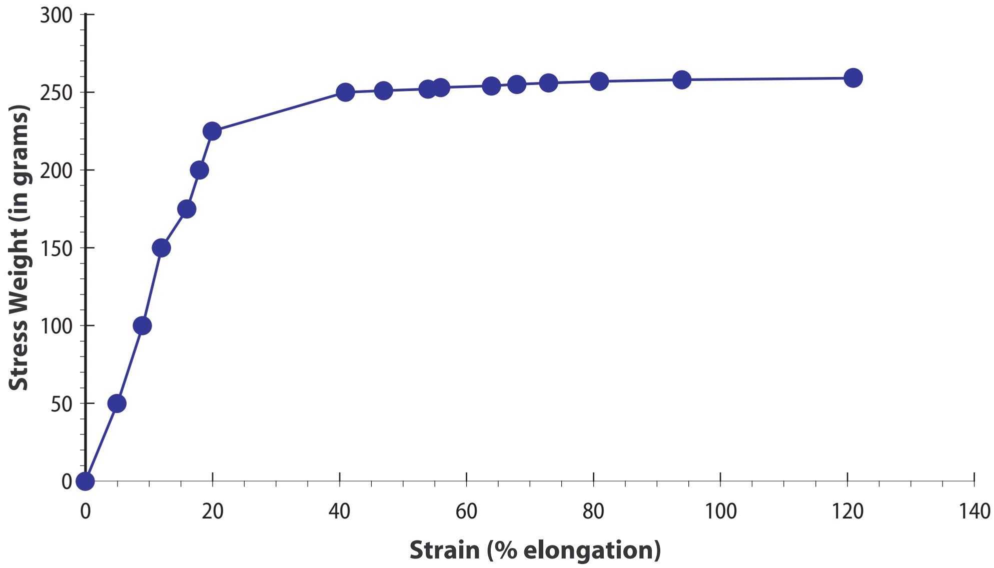
Sample	Direction	average % elongation
large garbage bag	machine	330%
large garbage bag	transverse	114%
latex glove	lengthwise	130%
latex glove	sideways	90%
ziptop bag	machine	160%
plastic wrap	machine	43%
rubber band	lengthwise	120%

The rate of pulling will cause differences in results, requiring students to replicate their pulling speed as best they can.

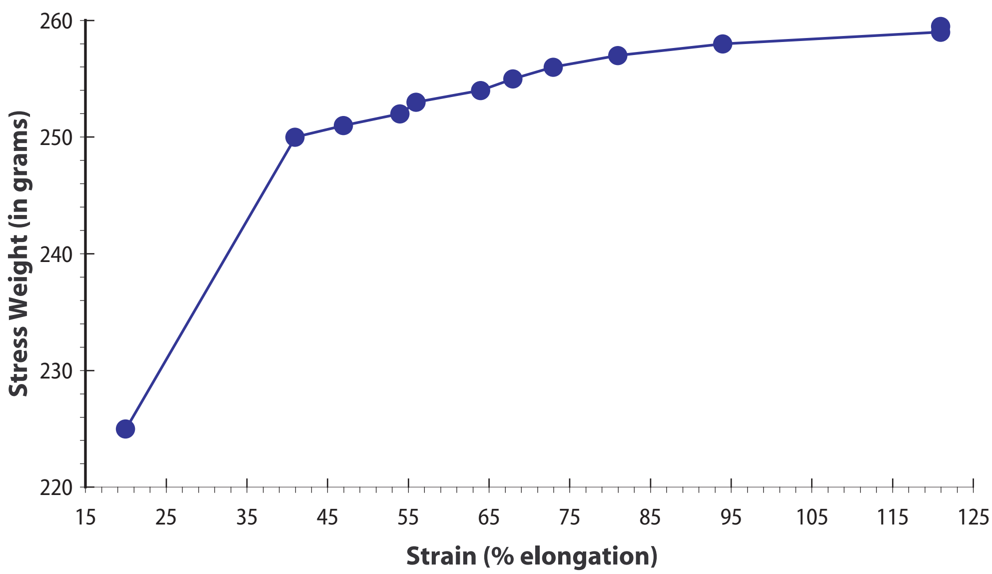
Sample data for Investigation #2

Mass of water (g)	Length (cm)	% elongation
0	4.75	
50	5.0	5
100	5.2	9
150	5.3	12
175	5.5	16
200	5.6	18
225	5.7	20
250	6.7	41
251	7.0	47
252	7.3	54
253	7.4	56
254	7.8	64
255	8.0	68
256	8.2	73
257	8.6	81
258	9.2	94
259	10.5	121
259.5	10.5	121
break	10.5	121

Tensile Test Poly Film (Entire Range)



Tensile Test Poly Film (Focused Range Near Break)



Plausible Answers to Questions

<u>In Investigation #1</u>

2.a. Compare and describe the difference in strain between the two samples. (If no difference is evident or if necking occurs, repeat Steps 1 and 2 while pulling at a faster rate.)

A: The student will feel greater strain when pulling the sample with the grain. The student is effectively pulling the polymer chains apart by breaking covalent bonds. The sample cut perpendicular to the grain will break more readily unless necking occurs (the reorientation of polymer chains along the direction of the stress). If necking occurs, repeat the test pulling each sample at a faster rate. The second sample breaks between the molecular chains interrupting intermolecular attractions. Students can feel the difference in the strength of the covalent bonds and intermolecular attractions.

3.a. Compare and describe the difference in strain between the two samples (parallel and perpendicular to the grain) and between the two sets (slow pull vs. very slow pull).

A: The students should see and feel the difference. Samples which are pulled more slowly will elongate more and the strain will not be as great at the start of the pull. (The strain will increase in both samples as they elongate.) The samples cut against the grain will show distinct narrowing or necking when pulled very slowly as the molecules reorient in the direction of the pull. Once the molecules reorient, the tenacity of the material should increase dramatically, possibly even to the point that the materials will be very difficult to break. Thus the first set (pulled faster) should break more readily with less elongation then the second set. Students should be able to explain the basics of this in terms of molecular orientation. Note, however, that factors such as density will have a significant influence on this behavior and complicate the explanation. (See the answer to question 4 in the "Following the Procedure" section below.) The thickness of the film will also affect the results so similar thicknesses should be used whenever possible.

3.b. Compare your results in terms of inherent strength and the application of the sample tested.

A: Answers will vary depending on the materials used. For example, trash bags are made so the grain is along the length of the bag. This orientation will provide extra strength along the length. This is important when garbage or other heavy materials are carried. The weight will be stressing the bag along the stronger direction. In contrast, the circumference of the bag needs to stretch more as materials are stuffed into the bag. The stretching, if done slowly, will actually increase the strength of the bag in this direction. Students may also comment on the general strength of the material used (e.g. broke easily regardless of direction relative to the grain).

4. Compare service needs with tensile results.

A: The students will describe a variety of different experiences depending on such factors as the polymeric composition, thickness, and density of the material. In general, the greater the commercial need for strength, the greater the tensile strength of the film.

<u>In Investigation #2</u>

8.a. What are some potential sources of error in this investigation? Explain.

A: The following are some possible answers. On other answers, look for a rational thought process in the explanation.

- Nicks in the edge of the sample are potential sites which may propagate a tear in the sample resulting in a premature failure of the sample.
- If the force is increased at an uneven rate, "bottle-necking" (or site-specific deformation) may occur. This might result in a weakness in the polymer chains in that area, again resulting in premature failure of the sample.
- Uneven application of the force over the sample width also causes deformation and potential weak spots.

8.b. Describe the broken sample pieces (including location of breaks, sample deformation characteristics, etc.) What conclusion might be drawn from each of these observations?

A: Here again are some possible answers. There may well be others.

Observation	Possible Conclusion
bottle necking	• uneven application of the force • uneven rate of application of force
tear at base of sample	• possible nick resulting from a problem when cutting out the form
clean tear	• sample torn with the grain of the polymer
"shattered" (rough) tear	• tear against the grain which follows the weakest polymer links

In Investigation #3

5. Describe the stretched sample.

A: Descriptions will vary but should include the resultant deformation, evidence of necking, and any other visible signs of change.

9.a. Compare and contrast the elongation results of plastics and elastomers.

A: Answers should be based on experimental data and should reflect a variety of percent elongation results. Most elastomers will stretch at least double their original length (that is, at least 100% elongation). Plastics will permanently deform whereas elastomers will not. Depending on how they are cut, plastics may show necking while pulled. If pulled slowly, those cut against the grain will have greater percent elongation than those samples cut with the grain.

9.b. What would happen to your percent elongation results if you increased the pulling speed on the test samples?

A: The percent elongation would generally be lower since the polymer was stressed more rapidly and the material's molecules would not have time to reorient. The sample would break more quickly (even in proportion to the greater rate of pull) and thus the %-elongation would be less.

9.c. How do results of percent elongation testing affect service use of the materials tested?

A: These response will vary based on material tested and the results obtained. In general, the plastic films would not function well in uses requiring rapid elongation.

Following the Procedure:

1. What happens to the polymer chains when the sample is stretched?

A: The polymer chains will elongate and line up in the direction of stretching. In blown film, the chains are more oriented in the machine direction (MD) than in the transverse direction (TD). Such film is much easier to tear in the machine direction; that is, when pulled in the transverse direction.

2. What structural differences account for the differences in behavior between plastic films and elastomers?

A: The polymer chains of an elastomer are cross-linked into a single network. The chains of this network tend to line up (become more ordered) when the elastomer is stretched but, as the result of the cross-linking, “bounce” back to the disordered state when released. The plastic films do not contain this cross-linking and thus remain stretched out.

3. Describe how the blow-up ratio in blowing film affects the ratio of tensile strength in the machine direction (MD) and in the transverse direction (TD).

A: Strength properties become more balanced in the machine and transverse directions as the blow-up ratio increases. The blow-up ratio is, in blow molding, the ratio of the diameter of the product (usually its greatest diameter) to the diameter of the parison from which the product is formed. In blown film extrusion, the blow-up ratio is the ratio between the diameter of the final film tube and the diameter of the die orifice.

4. How does density or crystallinity and polymer type (LDPE, LLDPE, HDPE) affect tensile strength and elongation?

A: Yield strength is the highest tensile force or stress to which a plastic molded shape or film may be submitted and still return to its original shape. It is the lowest stress at which a material undergoes plastic deformation. Below this stress, the materials is elastic; above it, the material is viscous. Elongation is the extension of the sample at the moment of rupture and is expressed as a percent of the original length. A higher density (crystallinity) resin has much higher yield strength and lower elongation than a lower density resin (i.e., HDPE vs. LDPE with LLDPE in-between). LDPE will also show significant necking compared to a similar sample of HDPE when both are pulled in the transverse direction.

Extensions and Variations

1. Tensile strength is also directly proportional to the crystallinity of the material. As the crystallinity of the polymer increases so does the material’s tensile strength. Make tensile bars from recycle #2 bags and also from recycle #4 bags. Determine whether the density of the film (#2 is high density and #4 is low density) also affects tensile strength. When a recycled #4 bag is filled with heavy groceries, it begins to grow as it is held. Is the stress being felt along the length of the polymer chains or are intermolecular attractions being stressed? (Primarily, the stress causes polymer chains to stretch and elongate so covalent bonds are predominately stressed.) How would the performance of the bag differ if the direction of extrusion ran the opposite direction? (The bag would be weaker. The bag material would possibly neck and stretch depending on the load in the bag.) As you stretch polymer chains you begin to further orient them or crystallize the material. How can you confirm this visually? (Change of color, use of polarized light)

2. Try bi-directional or layered materials (such as some brands of super strength trash bags). Is there a difference between samples cut with the direction of extrusion of the outer layer compared to samples cut perpendicular? (Since the material is bi-directional there will be little to no difference in results of the investigations.)

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